Technical Operating Report
B O B Approval No.________

AD-409 853

FINAL REPORT WEEK 20
STRUCTURAL DEVELOPMENT TEST
CASE M215.07

MTI-480

WEAPON SYSTEM 133A

22 July 1963

Contract Number AF 04(647)-243
Exhibit D, Paragraph IV.A.3

Prepared by

HERCULES POWDER COMPANY
CHEMICAL PROPULSION DIVISION
Bacchus Works
Magna, Utah

Prepared for

HEADQUARTERS
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
Los Angeles, California

HERCULES POWDER COMPANY
INCORPORATED

P. O. BOX 98 MAGNA, UTAH

22 July 1963

IN REPLY REFER TO: 1/4/10-713

Headquarters
Ballistic Systems Division
Air Force Systems Command
Norton Air Force Base
California

Attention: BSRPQ-1

Subject: "Final Report W2SD-20 Structural Development Test," Case M215.07, Report Number MTI-480, dated 22 July 1963, Contract AF 04(647)-243, Minuteman Stage III Rocket Motor M-57; WS-133A

Reference: Exhibit "D," Paragraph IV.A.3

Gentlemen:

In accordance with Exhibit "D" to Contract AF 04(647)-243, one copy of the subject report is hereby submitted.

Very truly yours,

J. L. Morse

J. R. BONNER, SUPERINTENDENT
AF CONTRACT SUPPORT for

JRB:JLMORSE:dd

Encl (Copy No. 1 of Report No. MTI-480)

cc: J. E. Greer (wo/encl)
Wilmington

W. E. Howell (wo/encl)
Wilmington

J. L. Shrout (wo/encl)

Hercules Powder Contract Management Office
AF Plant 81
Magna, Utah

Attn: Lt. Col. L. C. Wampler, Chief
(wo/encl)

Report No. MTI-480

Copy No. 13

Date 22 July 1963

FINAL REPORT W2SD-20
STRUCTURAL DEVELOPMENT TEST
CASE M215.07

Prepared by

T. I. Lester
Development Engineer
Minuteman Design

Reviewed by	Reviewed by	Approved by
R D Blodgett	J. L. Knearem	
for D. W. Austin	J. L. Knearem	W. L. G[illegible]r
Supervisor	Superintendent	Manager
Wing I - V Design	Wing I-V	Minuteman Project

FOREWORD

This report outlines work accomplished by the Case Design Group, Chemical Propulsion Division at the Bacchus Works of Hercules Powder Company for the continued development of Minuteman stage III Rocket Motor M-57.

Authority for preparation of this report is granted by Contract AF 04(647)-243, Exhibit D, Paragraph IV.A.3.

Published by

The Publications Group
Graphic Services Department
HERCULES POWDER COMPANY
Bacchus Works
Magna, Utah

ABSTRACT

Structural development test W2SD-20, case M215.07 was conducted 2 July 1962 at the Bacchus Works, Hercules Powder Company, to determine the structural integrity of the Wing II M-57E1 motor case when subjected to flight load conditions of axial load, shear load, and bending moment conducted under room temperature conditions.

Case M215.07 failed just forward of the thrust termination (TT) ports at an axial load of 57.87 kips, a shear load of 7.3 kips, and a bending moment of 865.8 in-kips in the area of failure.

Test results show that the equivalent axial load was 150.25 kips, the Poisson's ratio was 0.1711 and the modulus of elasticity was 4.20×10^6 psi. These values are for the area of failure.

It was concluded that the Wing II design case is capable of meeting and exceeding present design requirements specified in Boeing Document No. D2-3877-4.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SECTION I

INTRODUCTION

A. PURPOSE

Structural development test W2SD-20 was conducted as a part of a continued development program in the development of a lighter weight case for the third stage Minuteman. This test was one of a series intended to prove the new design in meeting or exceeding structural design requirements specified in Boeing Document No. D2-3877-4.

This test obtained information determining the structural integrity of the cylindrical section of the Wing II M-57E1 motor case under simulated flight requirements of axial load, shear load, and bending moment at room temperature.

The test was conducted 2 July 1962 by Hercules Powder Company at facilities located at Bacchus, Utah.

B. TEST OBJECTIVES

Test objectives were:

(1) To determine the physical capabilities of the lightweight Wing II M-57E1 motor case under combined external loading of axial load, shear load, and bending moment at room temperature.

(2) To determine modulus of elasticity and Poisson's ratio values for the critical areas of the case at room temperature.

SECTION II

TECHNICAL DISCUSSION

A. TEST SPECIMEN DESCRIPTION

The test specimen was a standard Wing II motor case (Ref: HPC drawing 01A00221) number M215.07 constructed of Spiralloy. The nominal outside diameter was 37.5 in. and the distance between tangent lines was 43.0 in. Case configuration is described in the following paragraphs:

1. Cylindrical Section

The cylindrical section of the case consisted of seven layers of 90° windings and six layers of 14.5° helical windings; the thrust termination (TT) port areas were each additionally reinforced with six glass wafers and six TT ply mats. The theoretical thickness was 0.16 in. except in the TT port reinforced area. (The case was pressurized to 50 psig to simulate the structural support received from propellant.)

2. Domes

The forward and aft domes were wound with four layers of 14.5° windings. The nozzle port areas on the aft dome were additionally reinforced with four glass wafers 16, 17, 18, and 19 in. diameter, respectively. The minimum theoretical thickness at the tangent line was 0.06 in.

3. Forward Skirt

The forward skirt buildup consisted of two layers of 14.5° windings, nine layers of reverse 143-weave glass cloth, one layer of 90° windings and three layers of 90° nylon roving. The nominal wall thickness was 0.17 in. and the length was 12.575 in., measured from the forward tangent line. For additional reinforcement, a 0.250 in. thick aluminum ring sleeve (Figure 1) was internally bonded to the inner surface of the skirt to ensure that failure would occur in the cylindrical section of the case.

4. Aft Skirt

The aft skirt buildup consisted of two layers of 14.5° windings, 22 layers of reverse 143-weave glass cloth, one layer of 90° winding, and three layers of 90° nylon roving. The nominal wall thickness was 0.313 in. and the length, measured from the aft tangent line, was 6.2 in.

In the manufacture of this case, the resin went through a two-cycle cure. Lamination materials used were Union Carbide's ERLA 2256 resin and HTS 144 ends/in. glass roving.

In preparation for the test, a metal-reinforced R & D section was attached to the forward skirt and a reinforce second-to-third stage interstage section was fastened to the aft skirt.

B. TEST PROCEDURES

After installation of the instrumentation (Figure 2), the assembly was mounted in an upright position in the compression load testing device as shown in Figure 3. This device consisted of three hydraulic rams designated P_1, P_2, and P_3. Ram P_1 was positioned on the base at point 0° and ram P_2 at 180°. P_3 was mounted on the crosshead 70 in. forward from the center of the TT port area at 180°. The force from P_3 was normal to the longitudinal centerline of the case.

The instrumentation was attached to the recorders and checked for accuracy (polarity, calibration). Next, the load was applied as programmed on the Y-T plot (Figure 4).

C. TEST RESULTS

The test results outlined below indicate that test objectives were satisfactorily met. Actual traces of the applied loads are shown in Figures 5 through 7. Test data are shown graphically in Figures 8 through 13 and are listed in Tables I through IV.

The mode of failure was a circumferential buckling of the cylindrical section approximately 10 in. forward of the thrust termination (TT) ports.

1. Physical Capabilities

Ultimate capability of the case in the area of failure was:

(a) Axial load = 57.87 kips

(b) Shear load = 7.3 kips

(c) Bending moment = 865.8 in. -kips

The equivalent axial load for the above condition is 150.25 kips. This load was calculated using the following equation:

$$P_{eq} = P_a + 2\ M/R$$

where:

P_{eq} = equivalent axial load

P_a = applied axial load

M = applied bending moment

R = radius of the case

The loads experienced by the forward and aft tangent line at time of failure are:

		Fwd Tan. Line	Aft Tan. Line
(a)	Axial load	57.87 kips	57.87 kips
(b)	Shear load	7.3 kips	7.3 kips
(c)	Bending moment	697.9 in-kips	1011.8 in-kips
(d)	P_{eq}	132.35 kips	165.83 in-kips

The final design requirements for the forward and aft tangent line per Boeing Document Number D2-3877-4 are:

		Fwd. Tan. Line	Aft Tan. Line
(a)	Axial load	23.1 kips	47.4 kips
(b)	Shear load	6.53 kips	4.9 kips
(c)	Bending moment	483.3 in-kips	727.9 in-kips
(d)	P_{eq}	74.88 kips	125.1 in-kips

For the above structural requirements (max. q α condition) the theoretical Spiralloy surface temperature if 150° F. At 150° F the ultimate structural capability of the case goes down 7 percent. Therefore, multiplying the ultimate case capability by 0.93 gives an equivalent ultimate capability of the case at the surface temperature of 150° F. The ultimate case capability then becomes 123.1 kips for the forward tangent line, 139.7 kips for the area of failure, and 154.2 kips for the aft tangent line.

Design requirements include a factor of safety of 1.25. The ultimate case capabilities show a margin of safety above design requirements in excess of 1.64 for the forward tangent line and 1.23 for the aft tangent line.

If a linear load distribution is assumed between the forward and aft tangent line, the required equivalent axial load for the area of failure is approximately 99.6 kips. Using this value the margin of safety in the area of failure, in excess of design requirements, is 1.40.

2. <u>Physical Properties</u>

Values for Poisson's ratio were calculated using strain gages O, P, R1-B and R1-C. R1-B was used instead of gage R1-A because upon examination of the data it was apparent that the gages were switched in position to that shown in Figure 2. Using the above gages the average value of Poisson's ratio at time of failure was 0.1711.

Values for the compressive modulus of elasticity were calculated from strain gage S and EDI-9. The modulus (E) for the cylindrical section (failure area) at time of failure as calculated from EDI-9 was 4.20×10^6 psi. The modulus for the area between TT ports as calculated from strain gage S was 3.39×10^6 psi. This value was also calculated at time of failure. These values agree with past test data.

Remaining instrumentation gave a wide variation of values for Poisson's ratio and modulus (E). The reason for this variation is unknown

SECTION III

CONCLUSIONS

The Wing II design case is capable of meeting and exceeding the present design requirements specified in Boeing Document No. D2-3877-4.

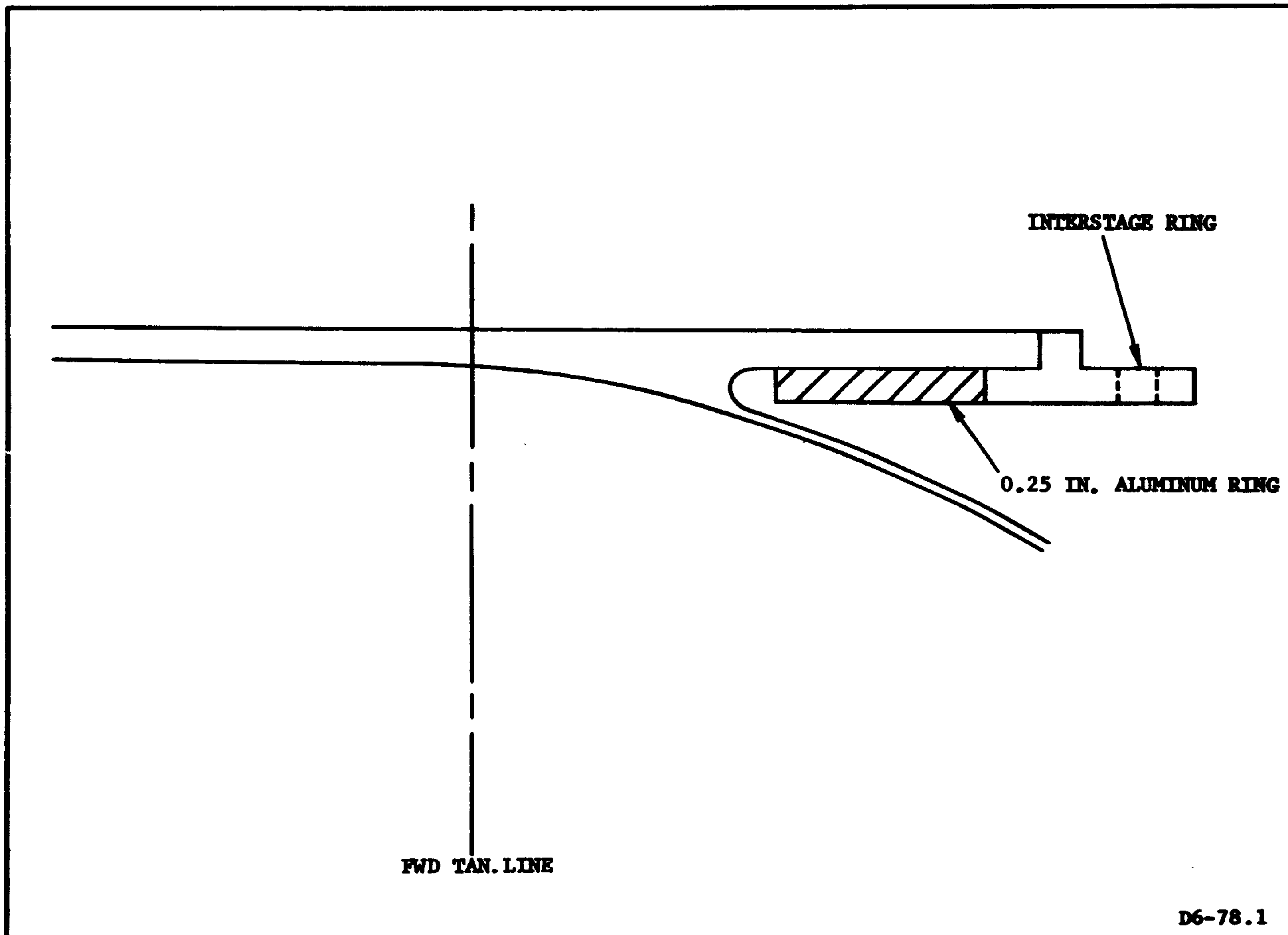
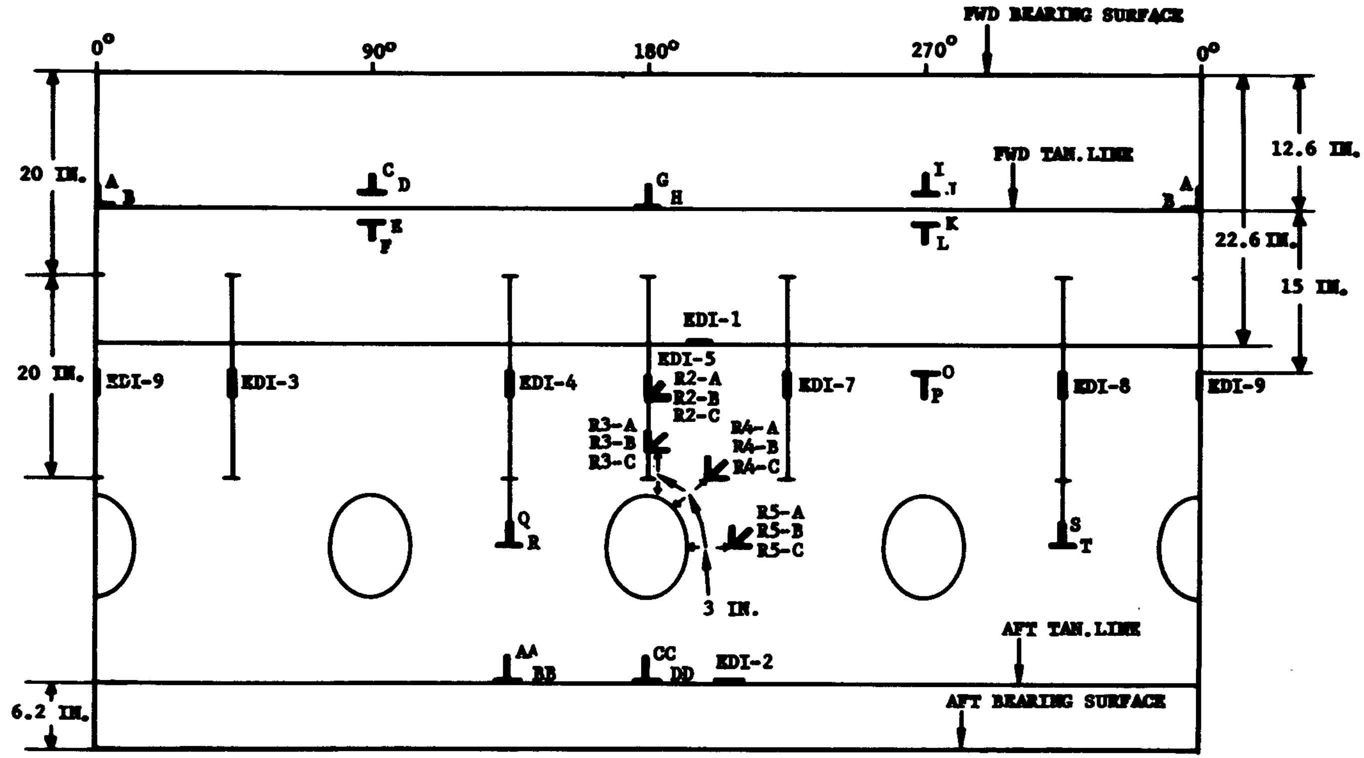


Figure 1. Specimen Reinforcement Diagram



EDI 10 and 11 Attached from loading head to base plate at 90° and 270°

D6-78.3

Figure 2. Test W2SD-20 Instrumentation Location

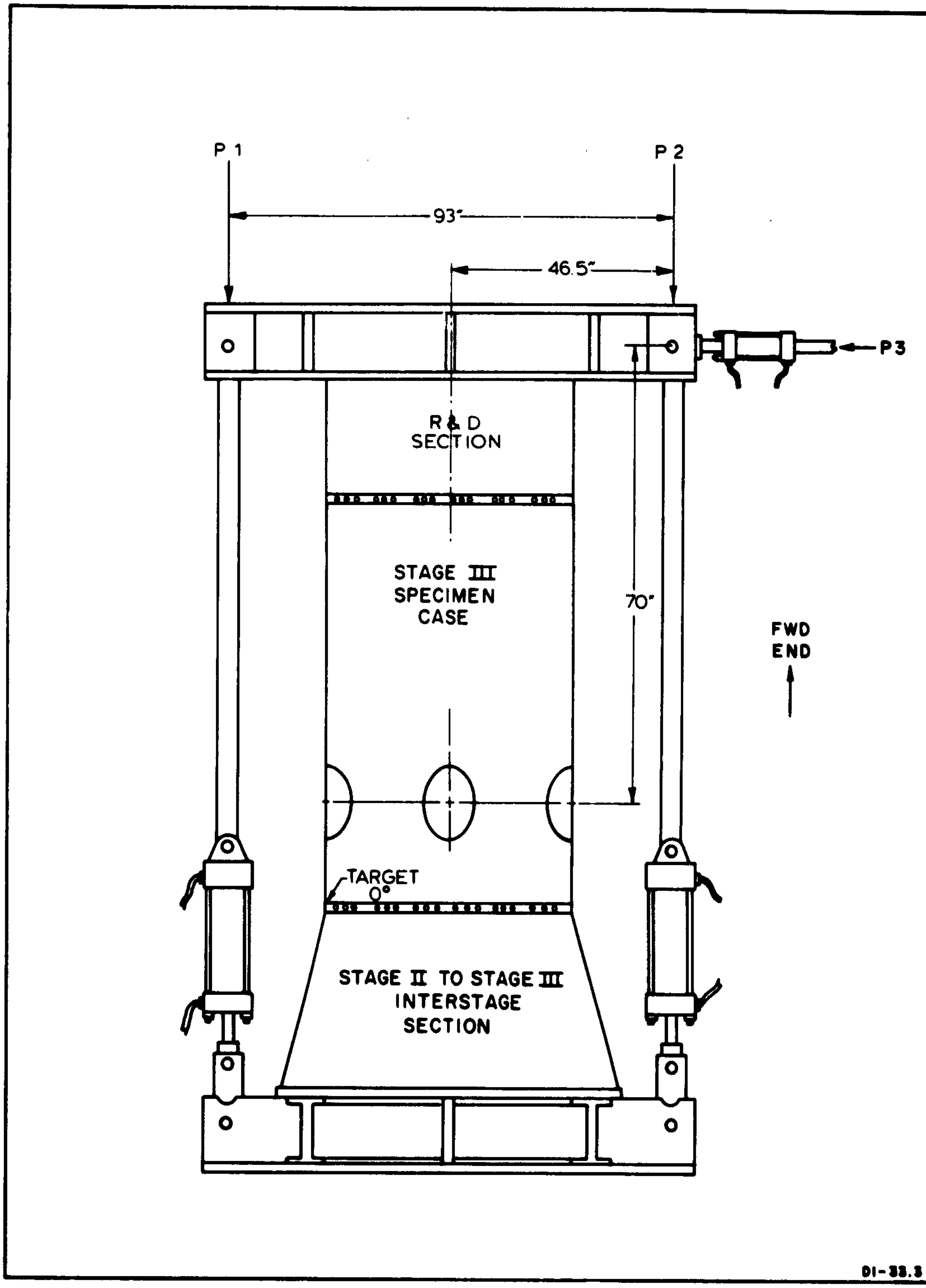


Figure 3. Test Setup

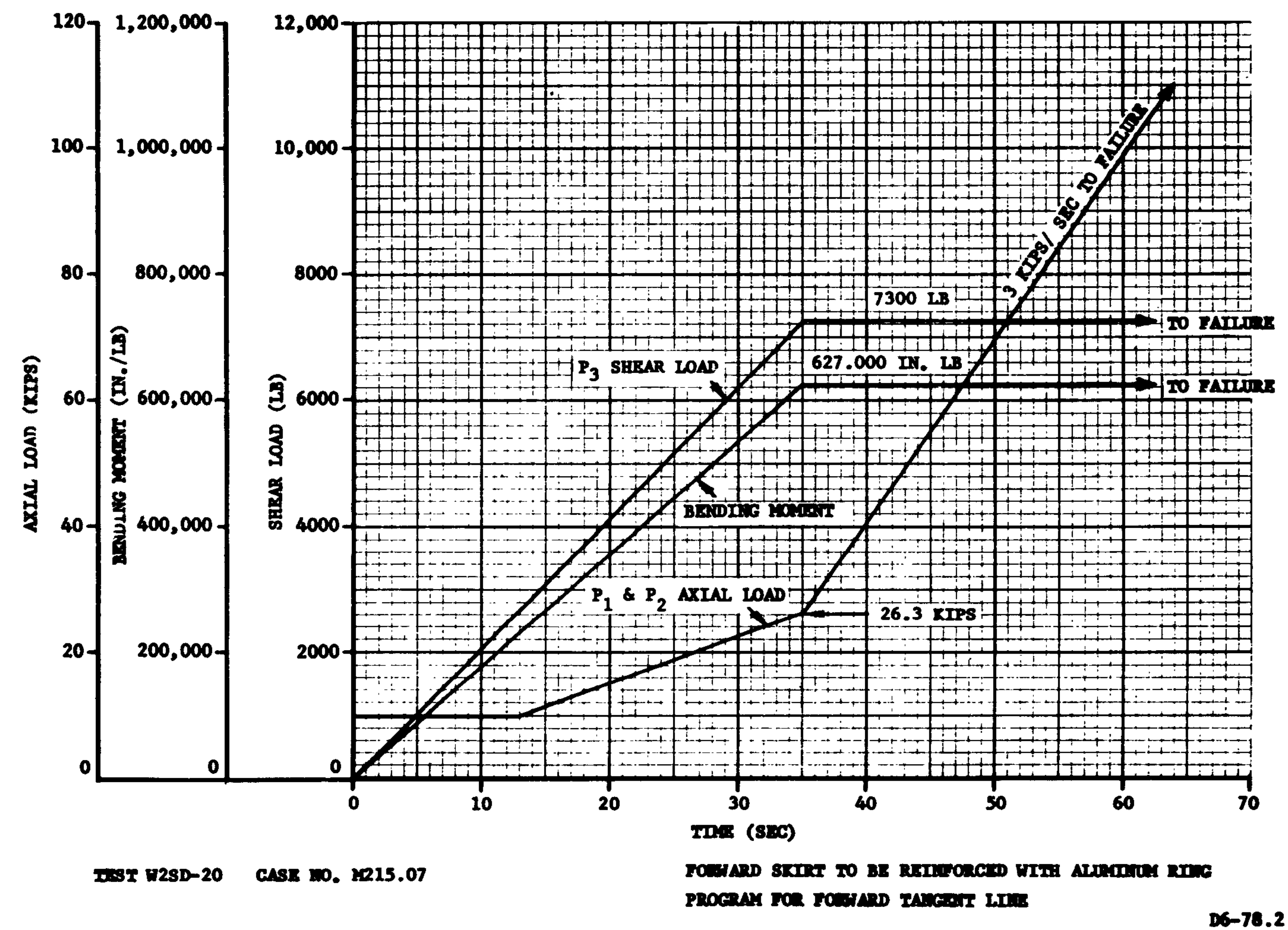


Figure 4. Programmed Loads (Y-T Plots)

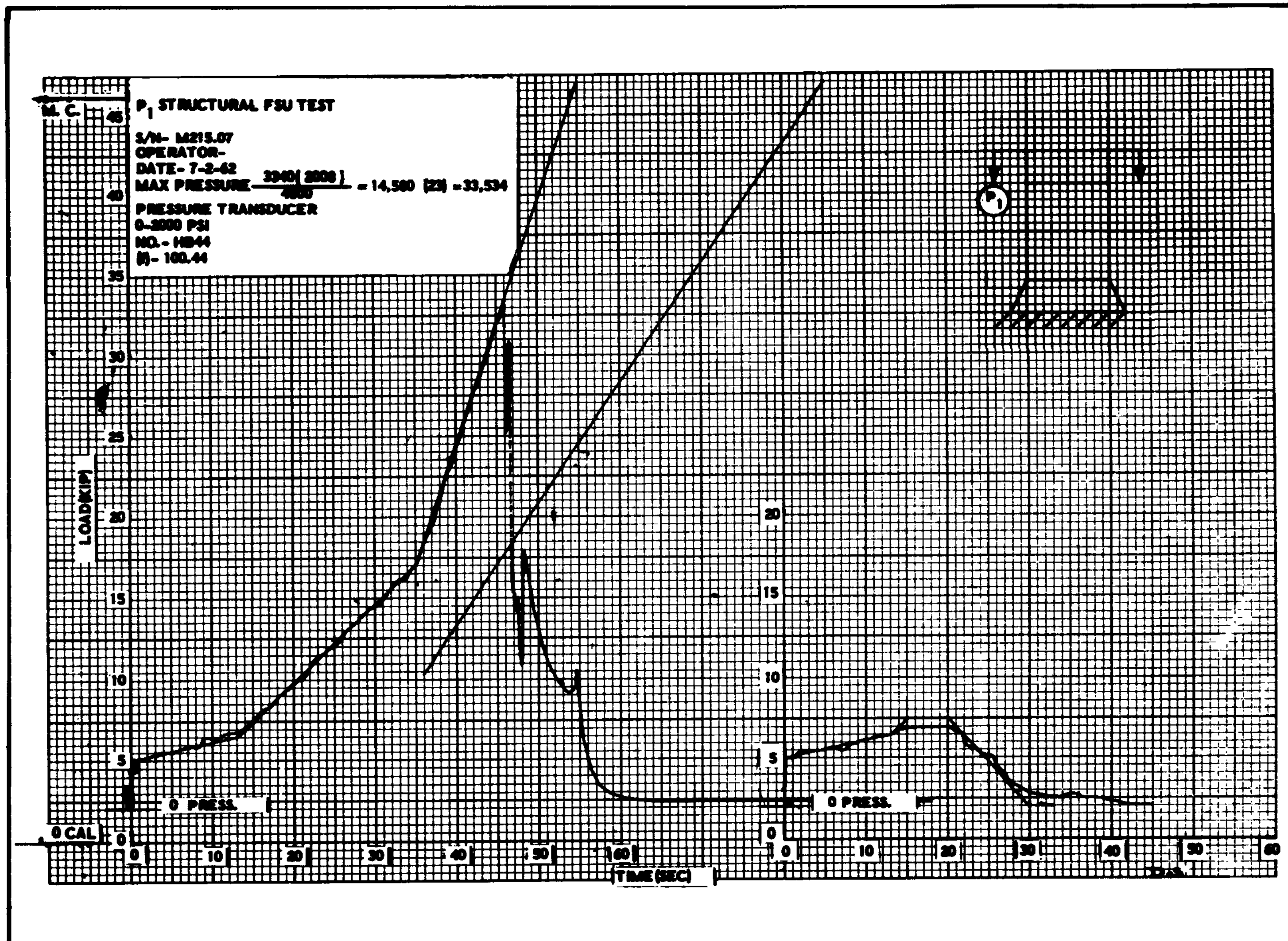


Figure 5. P_1 Compressive Loads vs Time Trace

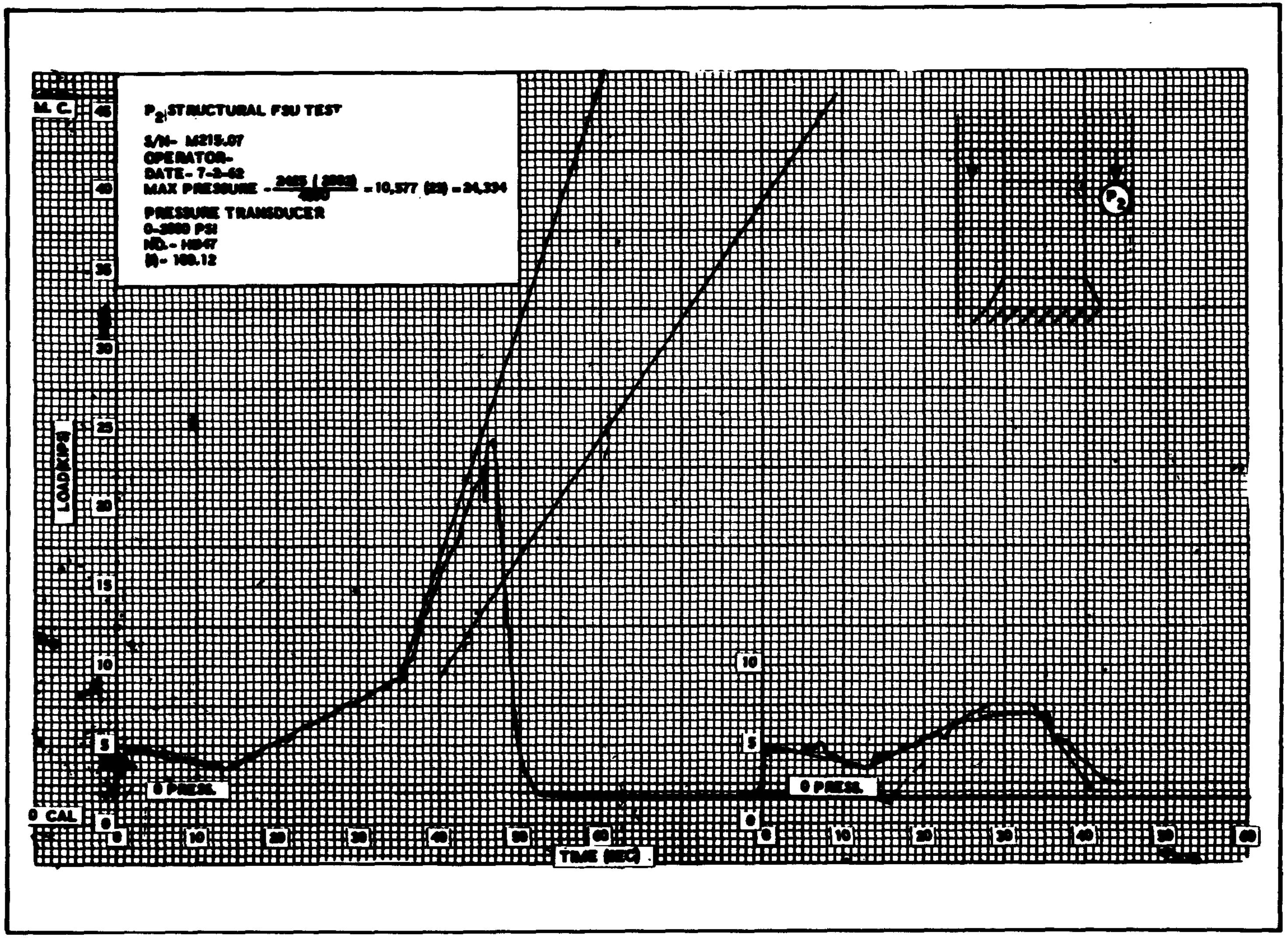


Figure 6. P_2 Compressive Loads vs Time Trace

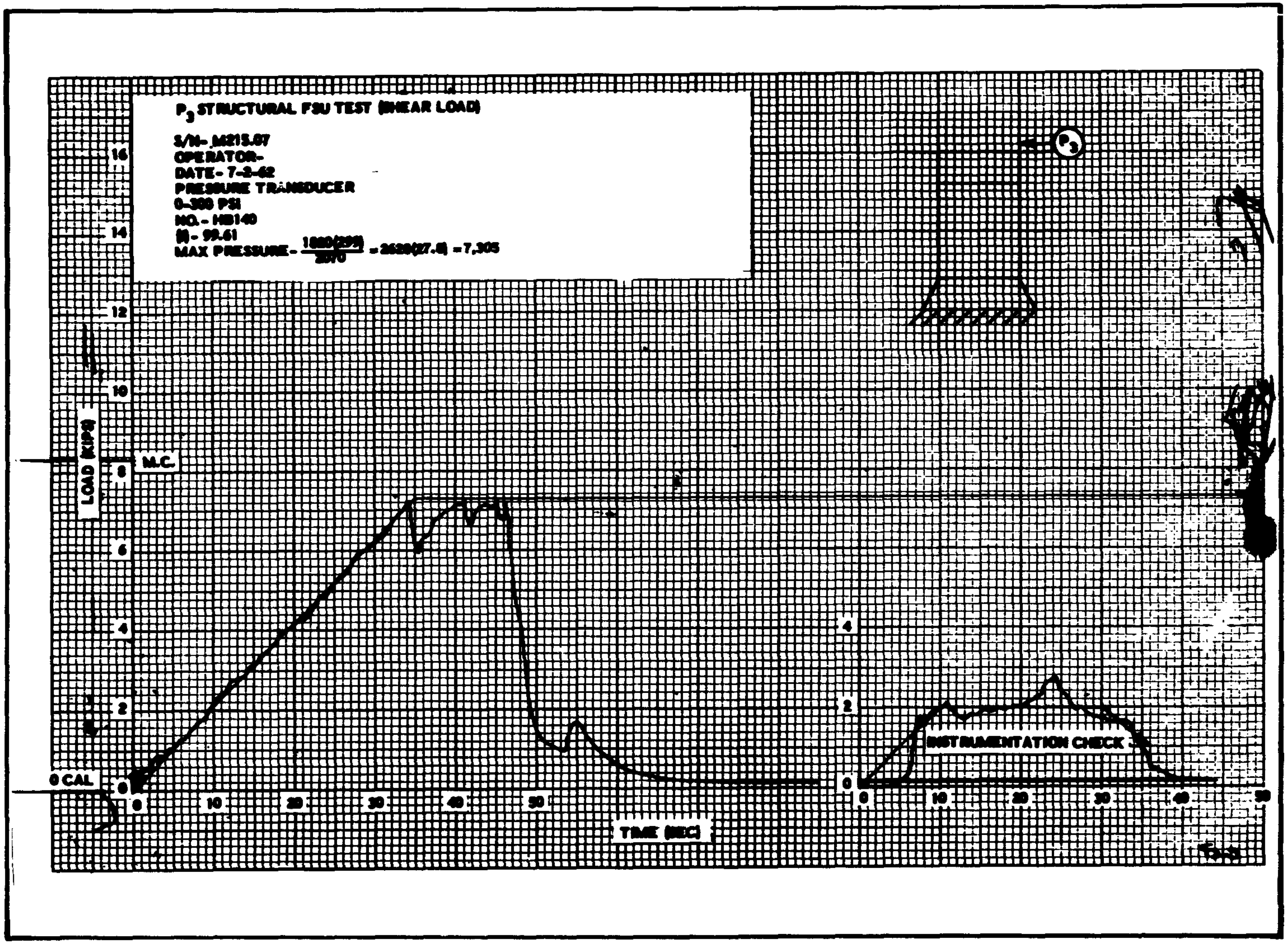


Figure 7. P_3 Shear Load vs Time Trace

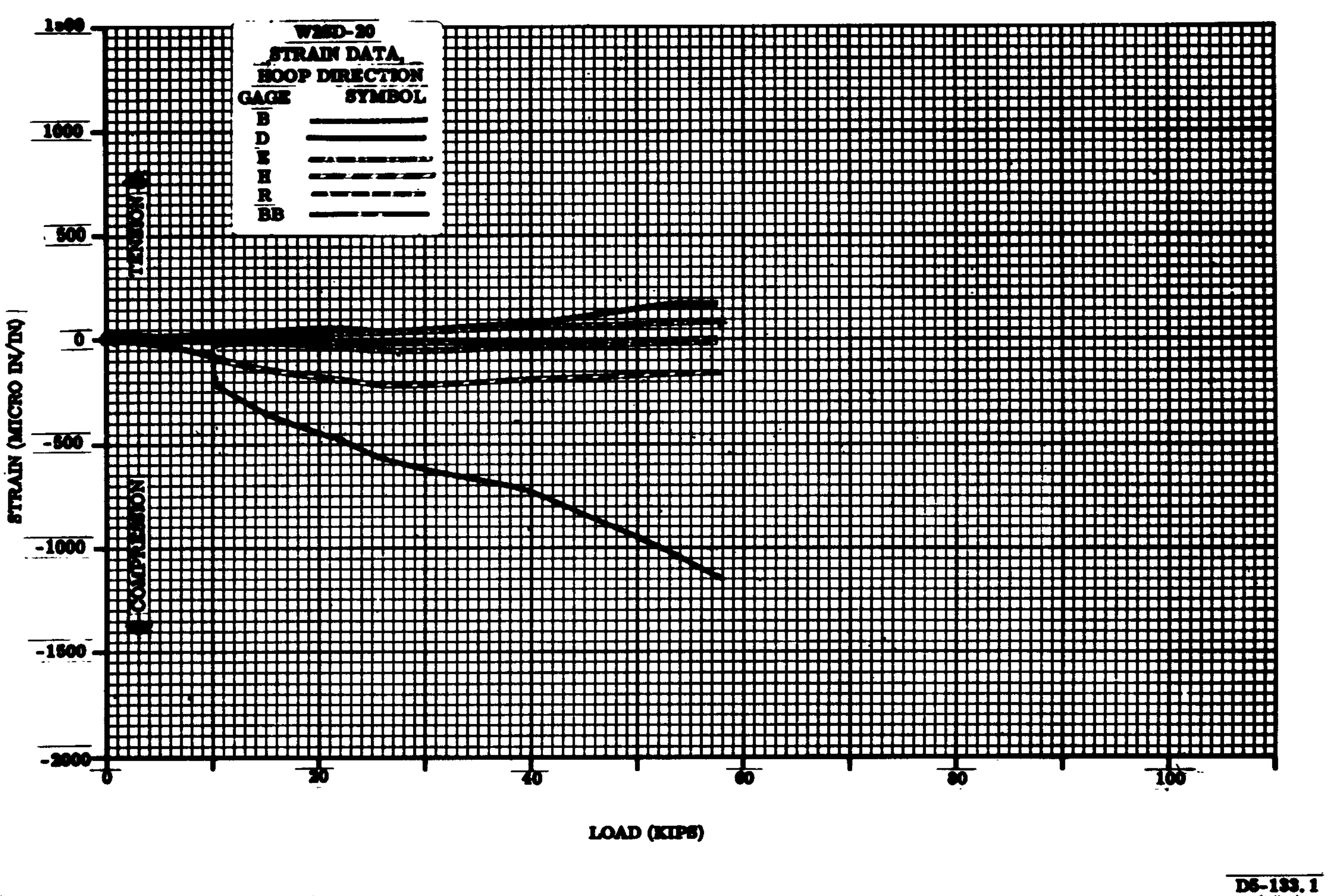


Figure 8. Hoop Strain vs Time (Sheet 1 of 2)

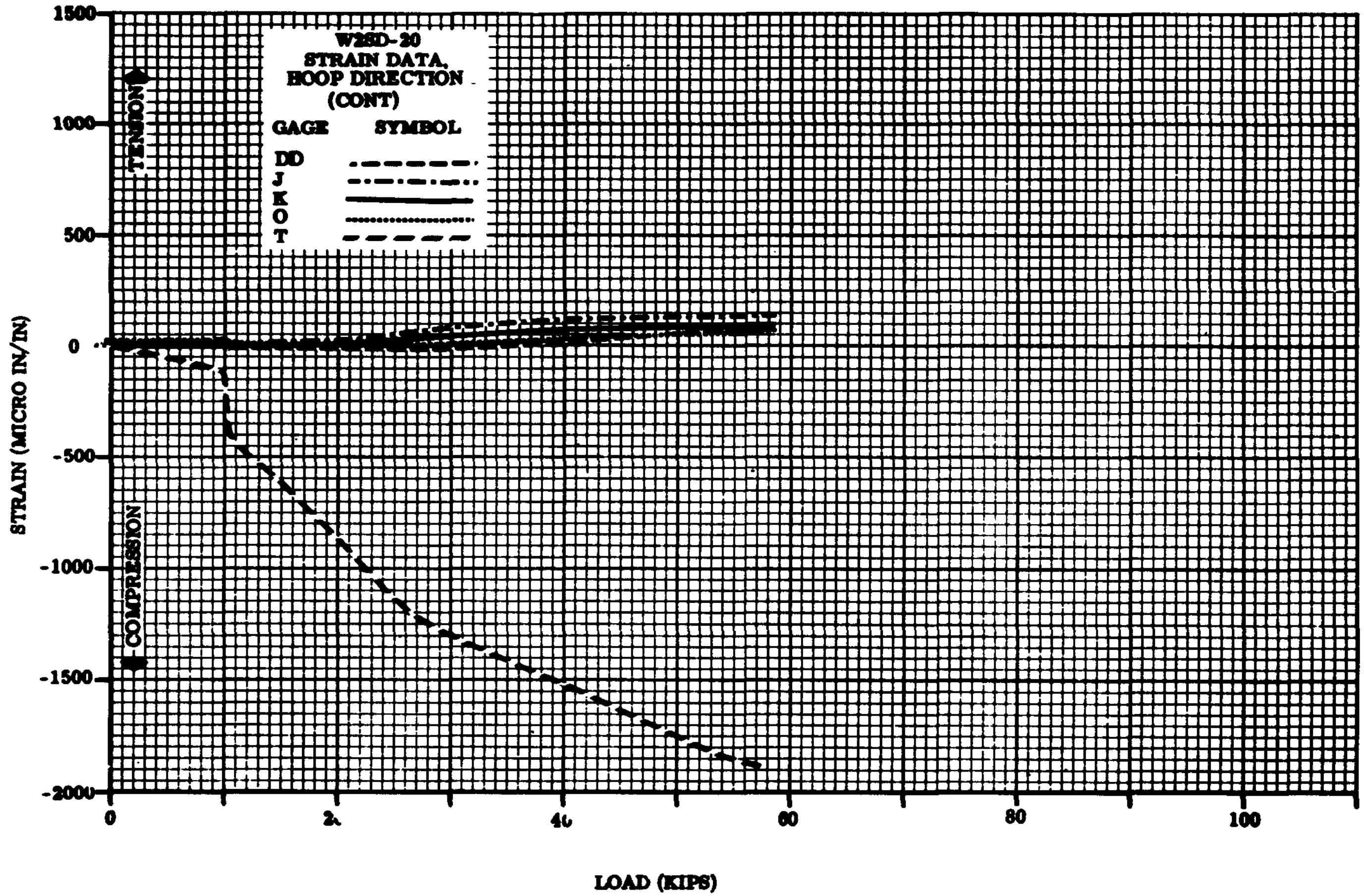


Figure 8. Hoop Strain vs Time (Sheet 2 of 2)

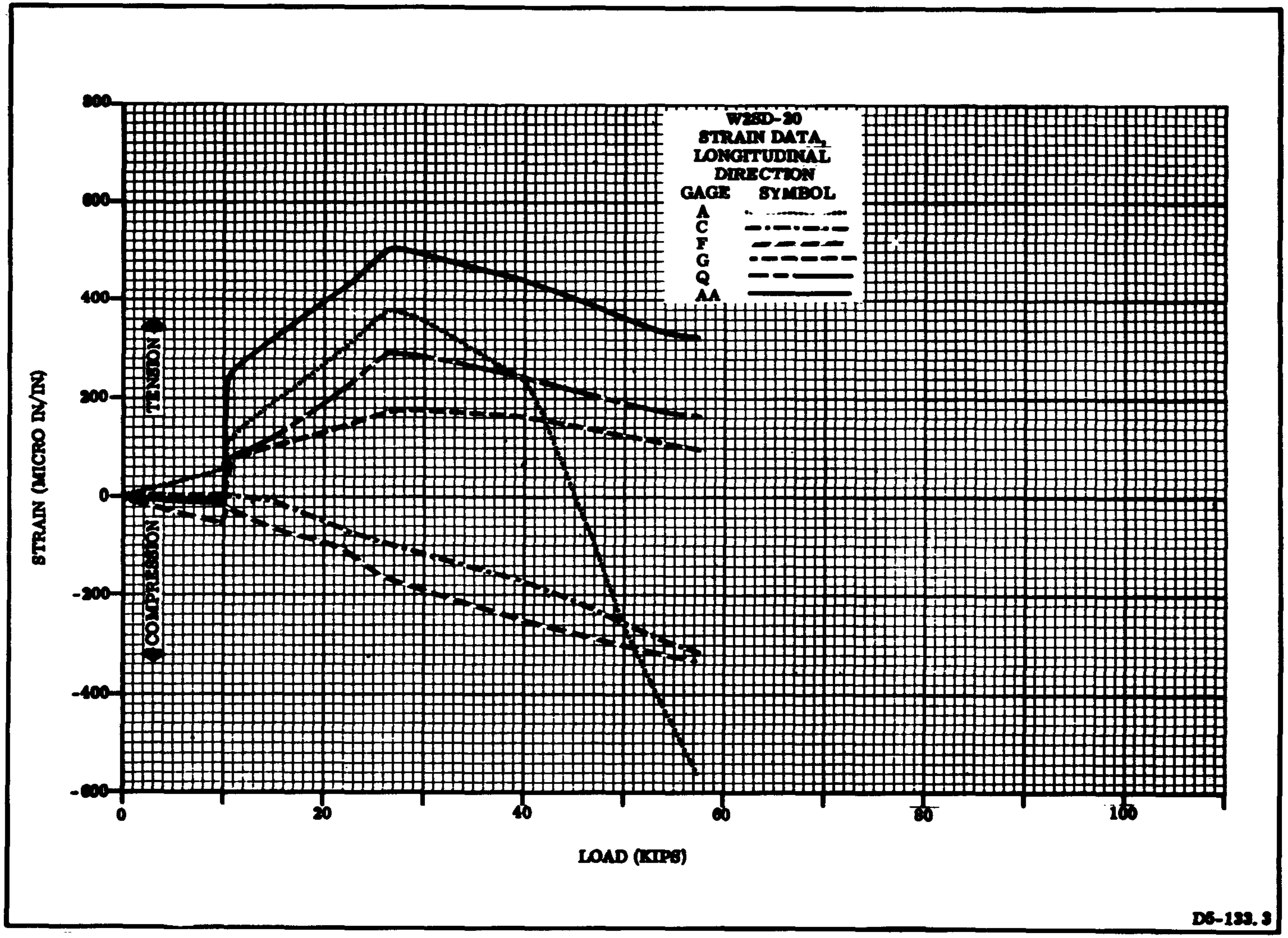


Figure 9. Longitudinal Strain vs Time (Sheet 1 of 2)

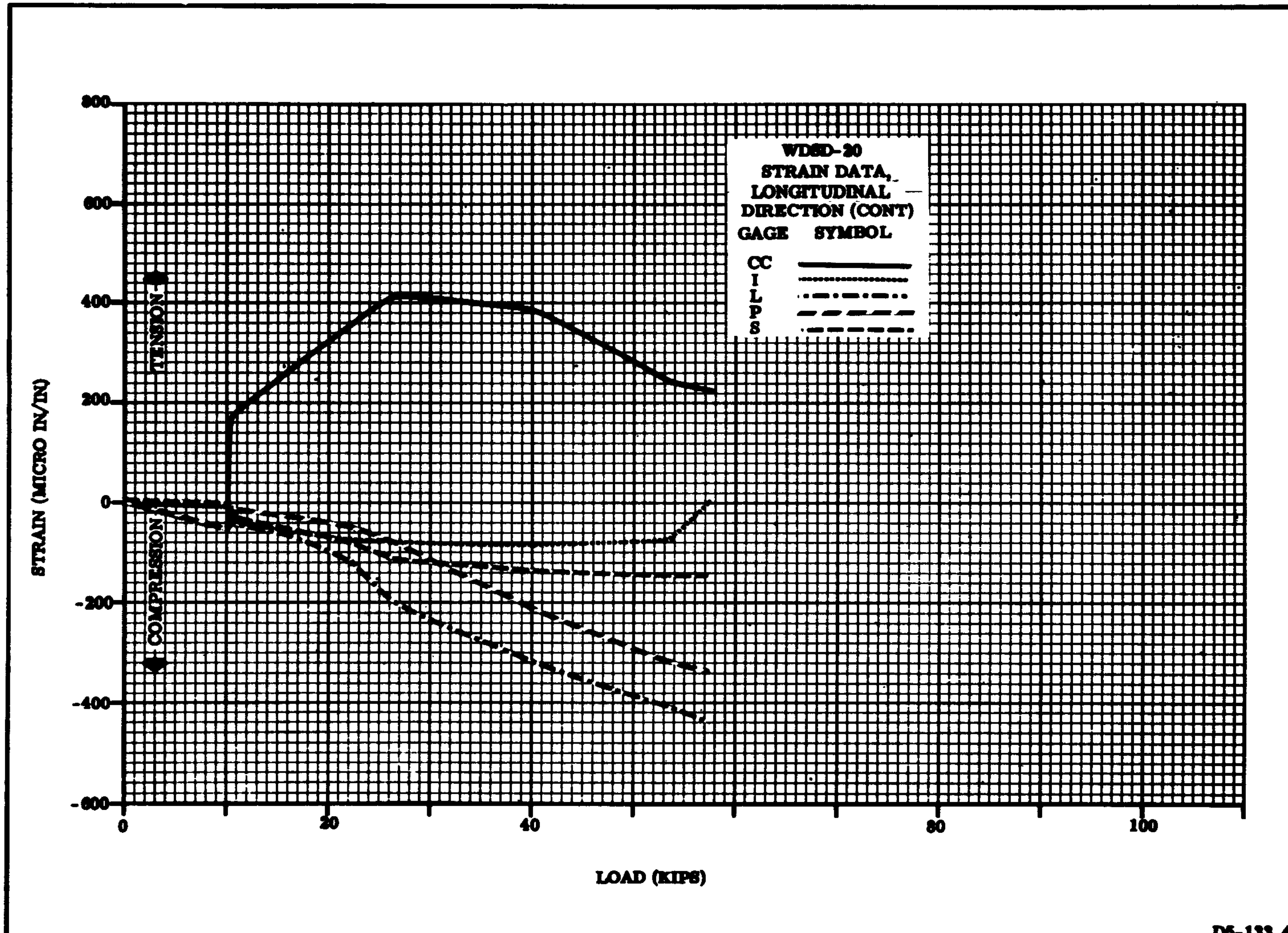


Figure 9. Longitudinal Strain vs Time (Sheet 2 of 2)

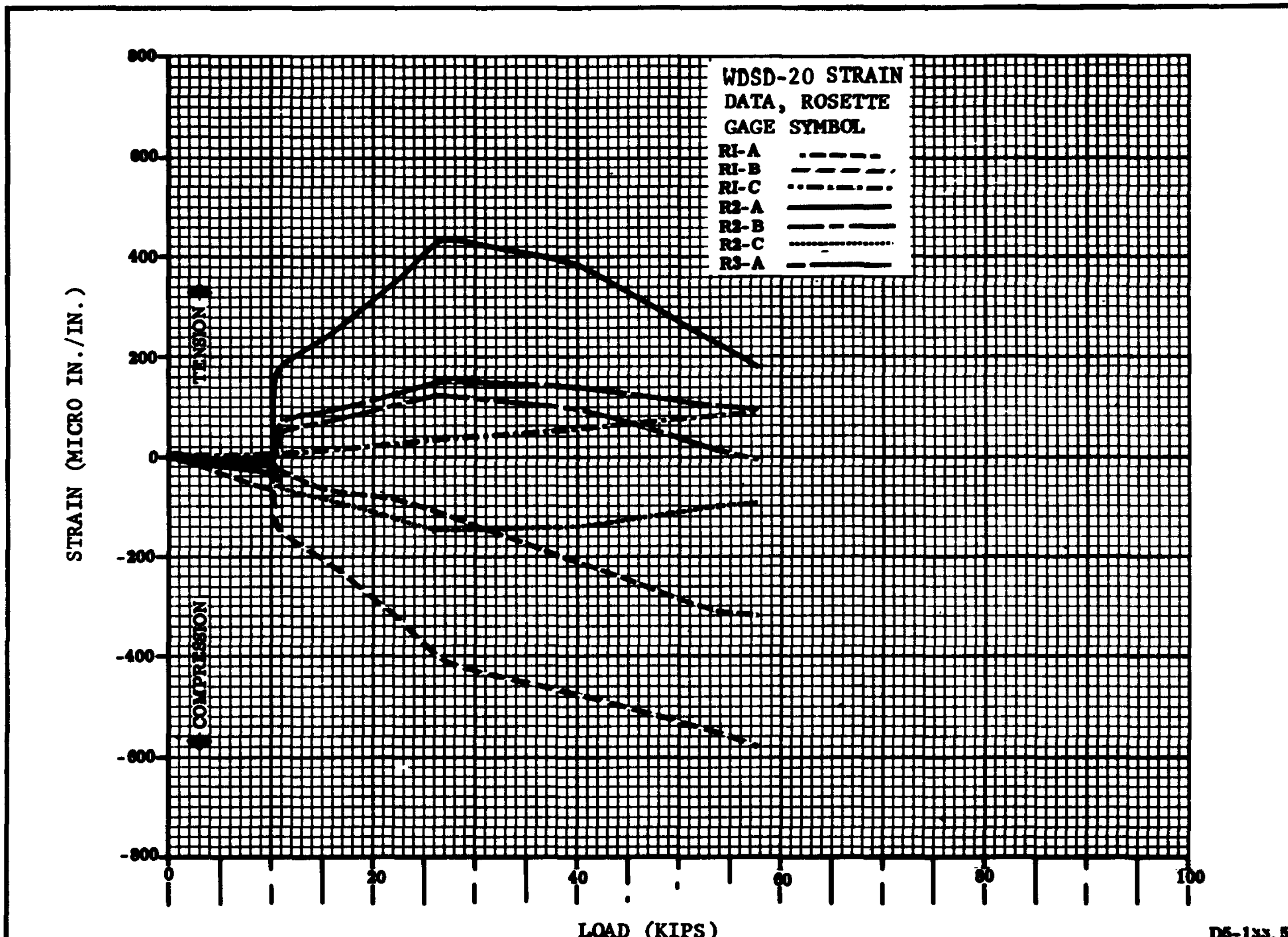


Figure 10. Rosette Gage Strain vs Time (Sheet 1 of 2)

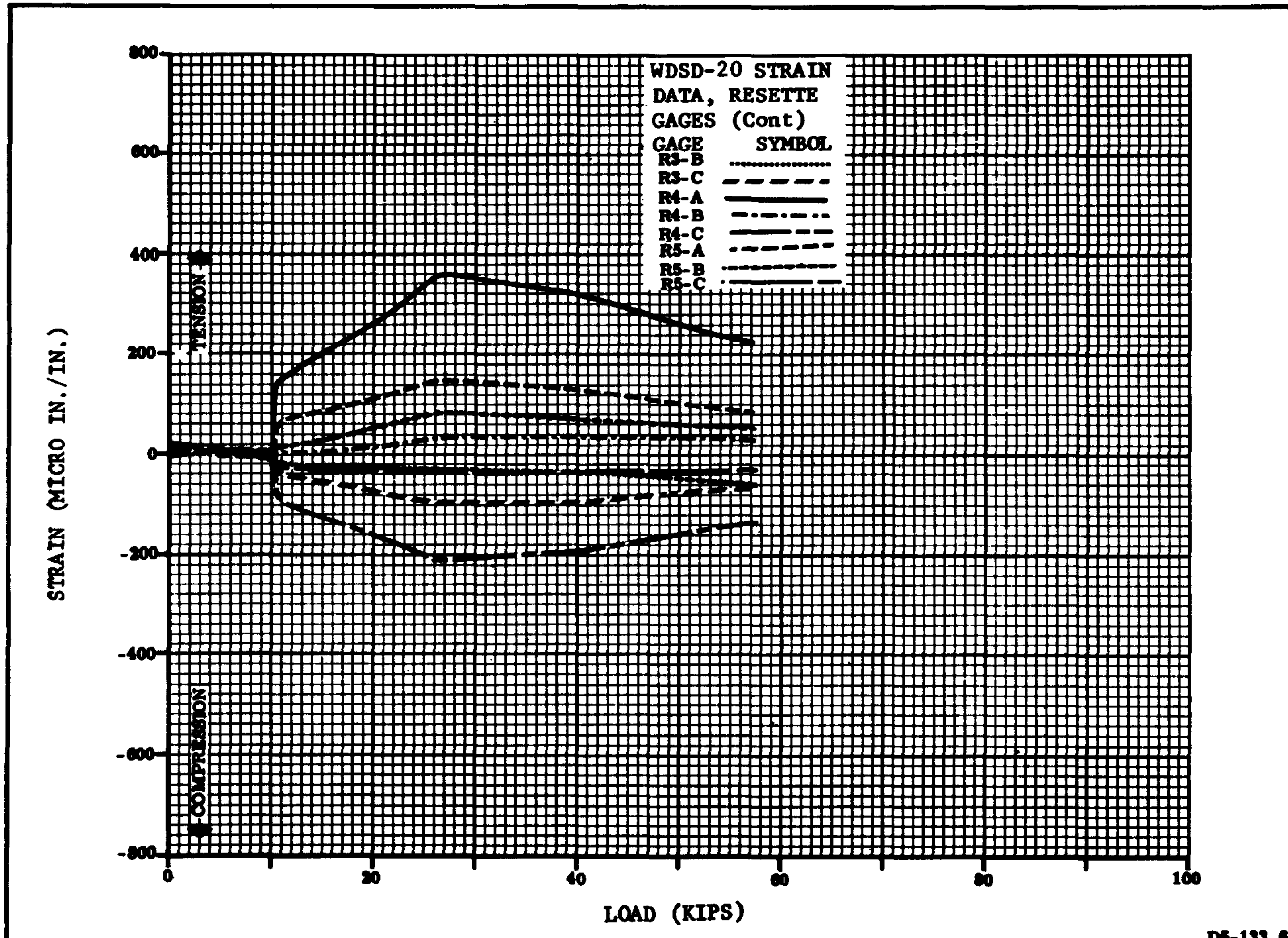


Figure 10. Rosette Gage Strain vs Time (Sheet 2 of 2)

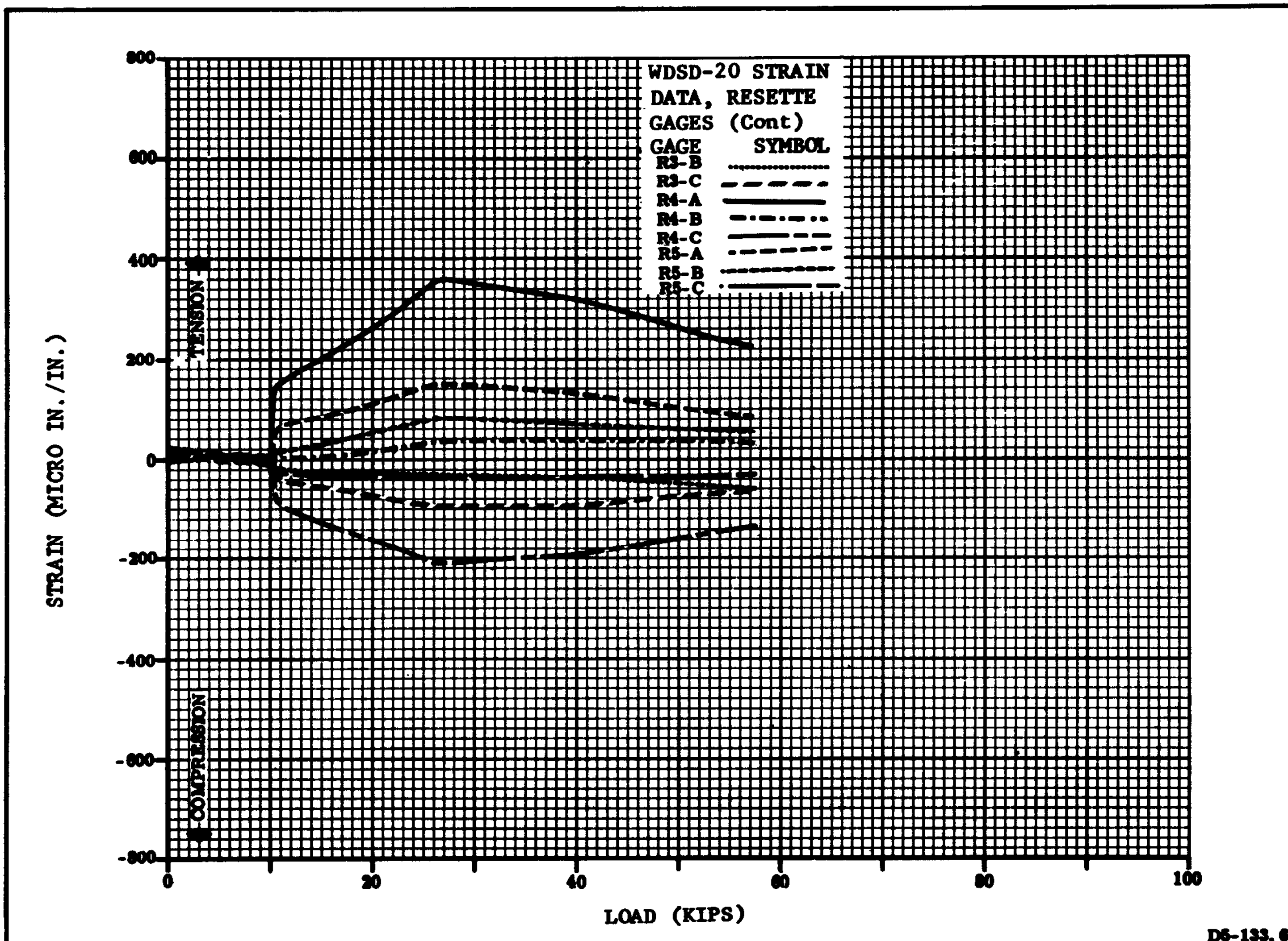


Figure 10. Rosette Gage Strain vs Time (Sheet 2 of 2)

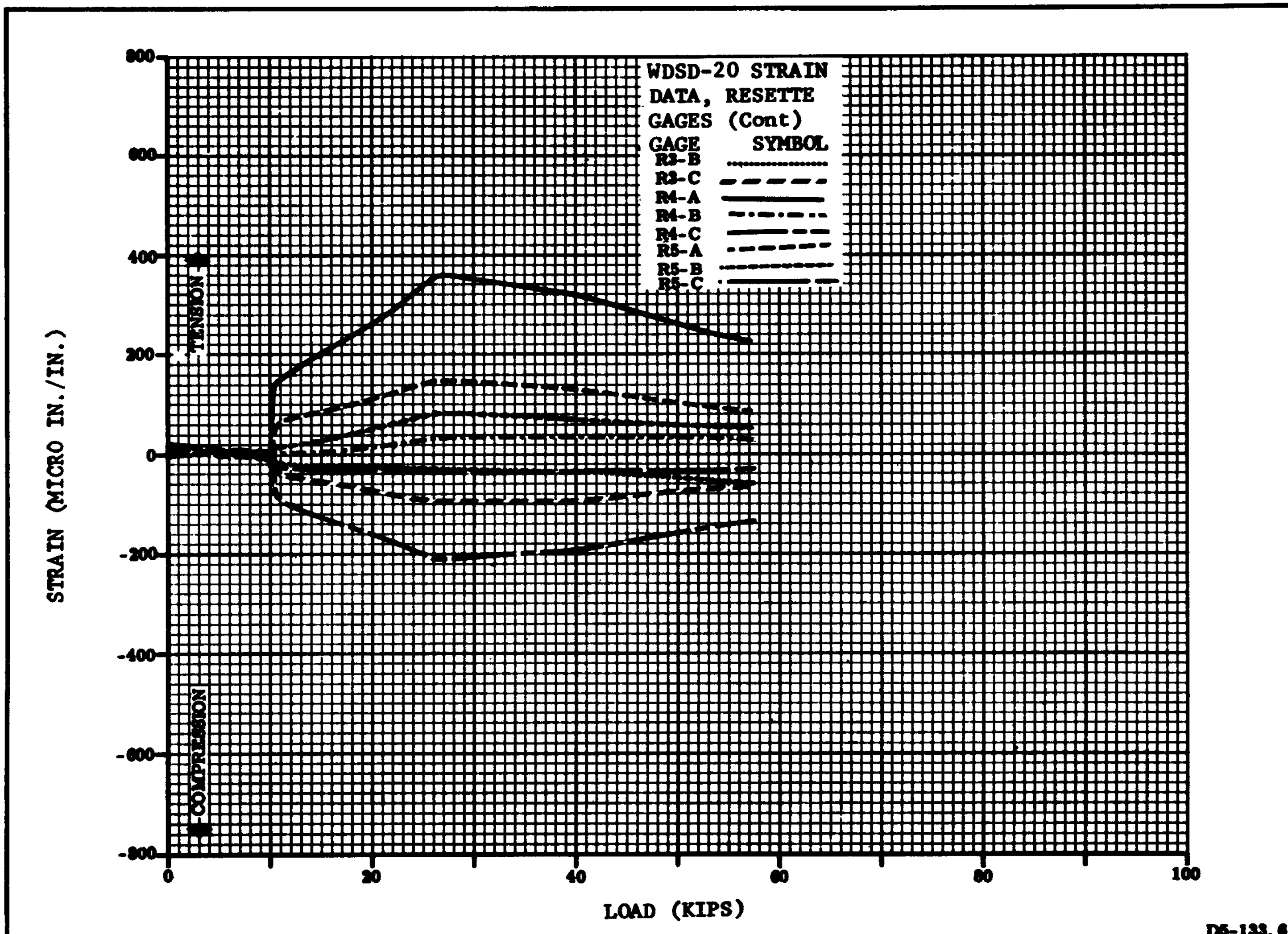


Figure 10. Rosette Gage Strain vs Time (Sheet 2 of 2)

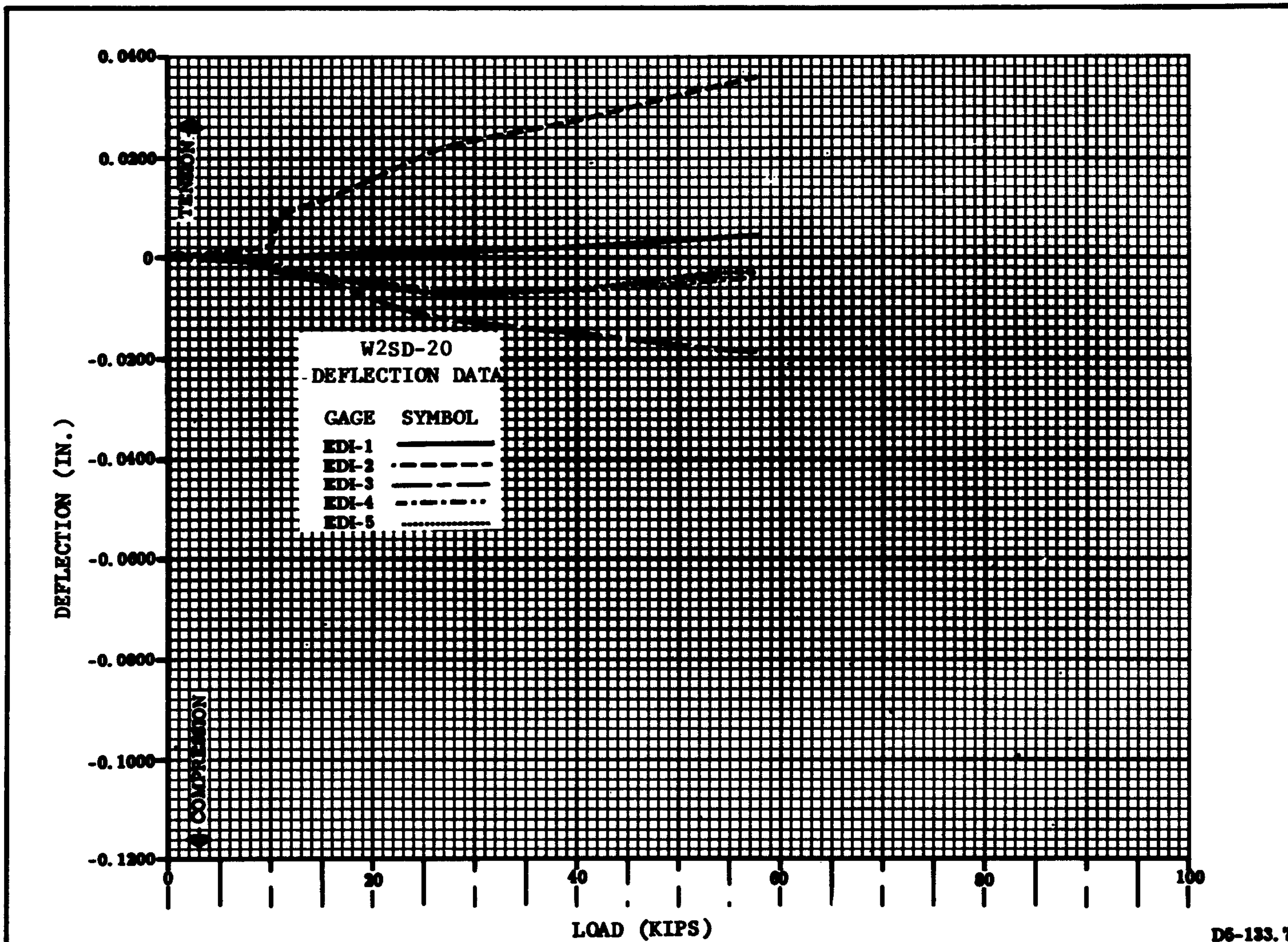


Figure 11. Deflection vs Time (Sheet 1 of 2)

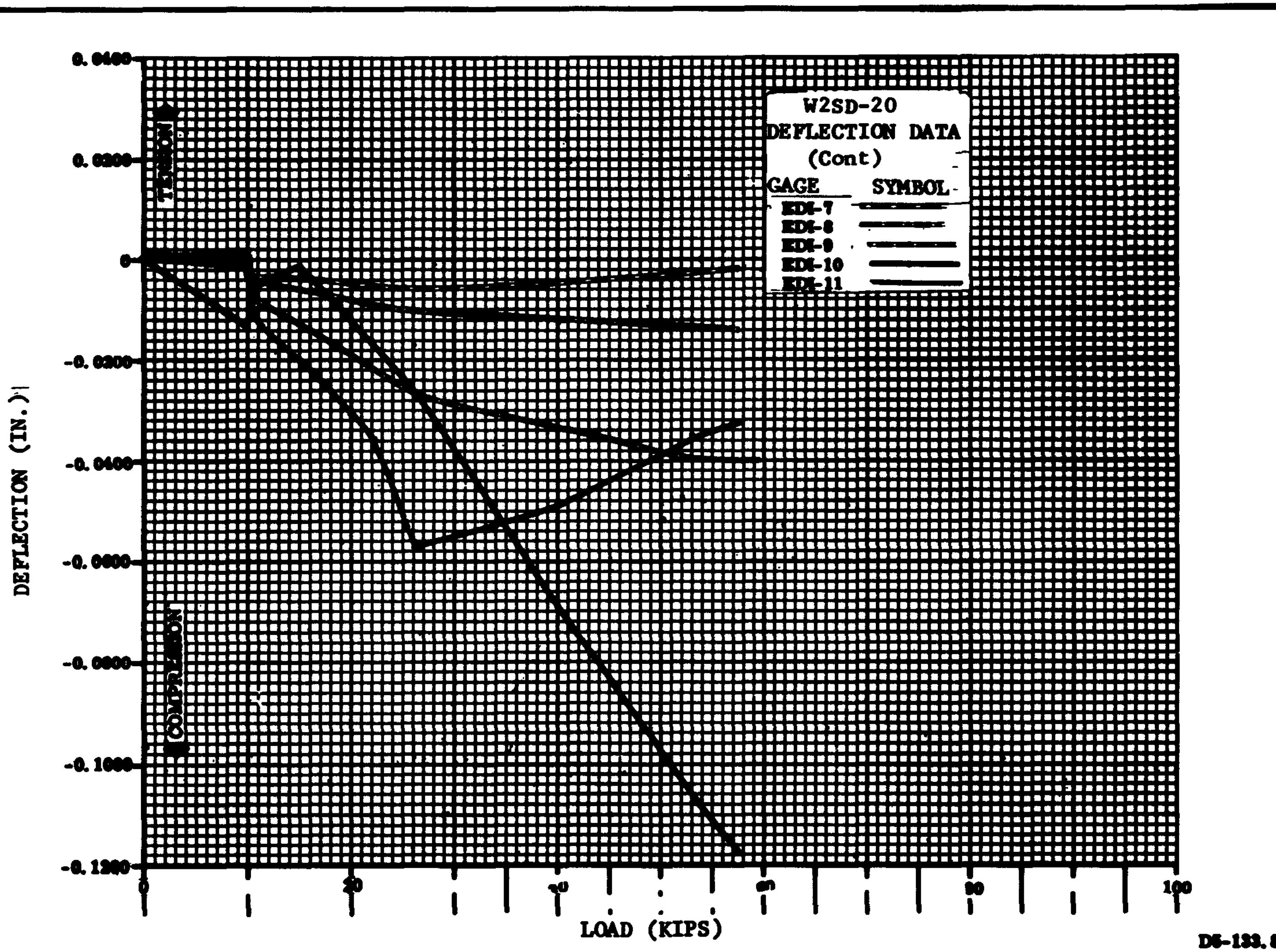


Figure 11. Deflection vs Time (Sheet 2 of 2)

Figure 12. Failure Area, 0°

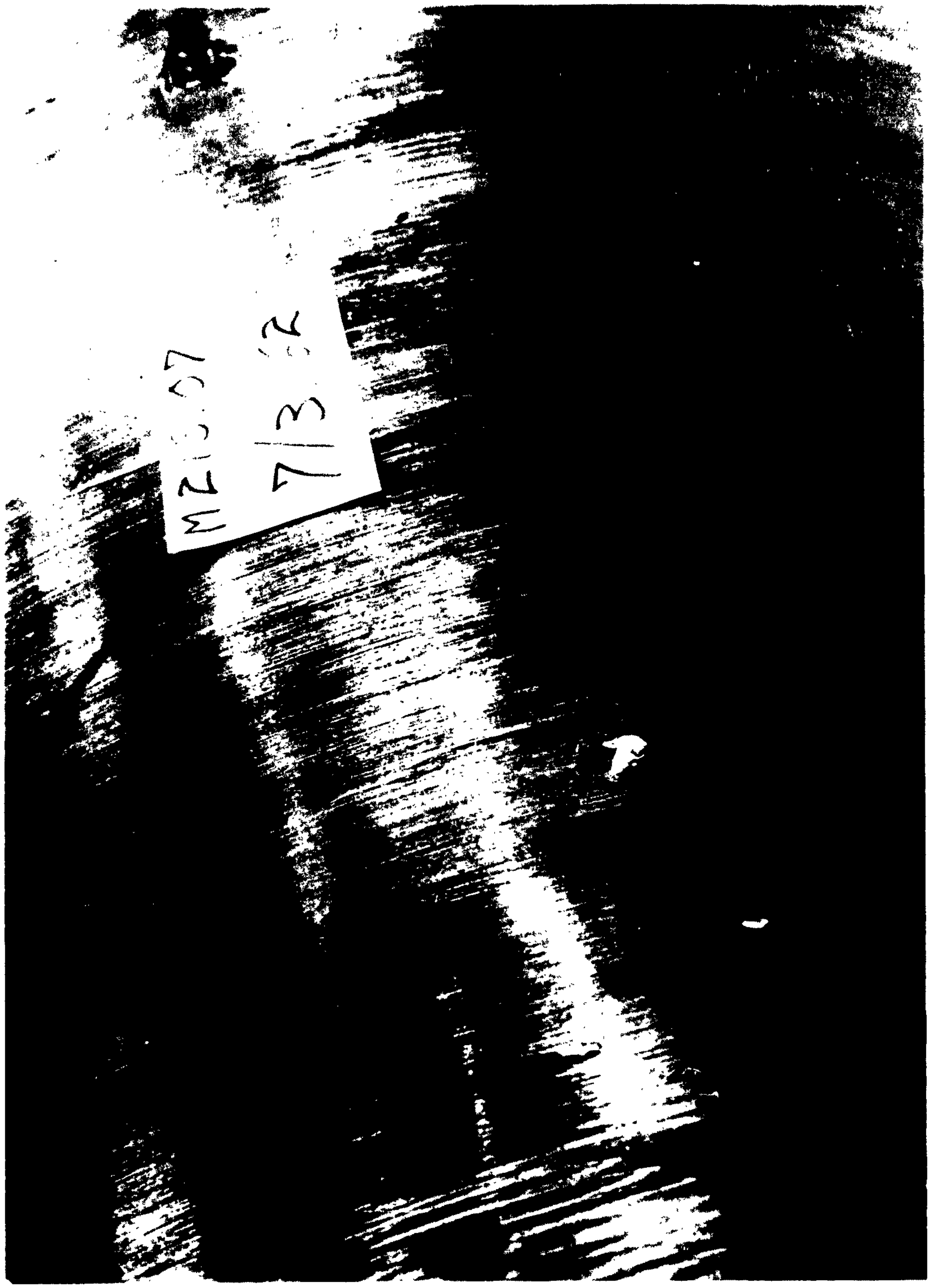


Figure 13. Failure Area, 90°

TABLE I

STRAIN DATA, HOOP DIRECTION

Gage Number	Time (sec)											
	-34.0	0	13	20	30	35	40	45	46			
	Pressure (psig)											
	0	10.0	10.3	15.0	22.3	26.1	40.0	53.7	57.8			
B	0	-72	-224	-368	-465	-561	-729	-1041	-1145			
D	0	16	24	40	64	32	72	176	176			
E	0	8	8	16	32	40	64	72	80			
H	0	8	-96	-144	-192	-224	-192	-160	-152			
R	0	8	8	16	48	56	40	16	16			
BB	0	0	0	-8	-24	-16	-16	-8	0			
DD	0	24	-8	-8	-8	-16	8	64	80			
J	0	8	0	8	24	64	112	128	240			
K	0	0	0	0	16	40	72	96	96			
O	0	8	0	0	0	0	24	56	64			
T	0	-104	-384	-617	-1001	-1202	-1522	-1842	-1874			
Minus sign indicates compression												

TABLE II

STRAIN DATA, LONGITUDINAL DIRECTION

Gage Number	Time (sec)											
	-34	0	13	20	30	35	40	45	46			
	Pressure (psig)											
	0	10.0	10.3	15.0	22.3	26.1	40.0	53.7	57.8			
A	0	56	112	192	304	384	240	-409	-561			
C	0	0	0	-8	-72	-96	-168	-296	-312			
F	0	-56	-24	-64	-104	-160	-256	-320	-336			
G	0	0	88	104	144	176	160	112	96			
Q	0	-8	80	120	224	296	248	176	168			
AA	0	-16	240	320	433	505	441	336	328			
CC	0	-8	168	248	360	417	392	240	224			
I	0	-8	-32	-56	-72	-80	-88	-72	8			
L	0	-56	-40	-56	-120	-200	-320	-409	-441			
P	0	-56	-8	-24	-48	-80	-216	-320	-336			
S	0	0	-32	-48	-80	-112	-136	-144	-144			
Minus sign indicates compression												

TABLE III

ROSETTE STRAIN DATA, CYLINDRICAL SECTION

Gage Number	Time (sec)											
	-34.0	0	13	20	30	35	40	45	46			
	Pressure (psig)											
	0	10.0	10.3	15.0	22.3	26.1	40.0	53.7	57.8			
R1-A	0	-56	-32	-56	-88	-112	-216	-312	-320			
R1-B	0	-26	-140	-204	-324	-406	-478	-556	-580			
R1-C	0	8	8	16	24	32	56	80	88			
R2-A	0	28	164	235	355	443	383	223	184			
R2-B	0	-16	42	62	102	126	96	14	-8			
R2-C	0	4	-62	-86	-126	-150	-140	-100	-92			
Minus sign indicates compression												

TABLE IV

ROSETTE STRAIN DATA, TT PORT AREA

Gage Number	Time (sec)											
	-34	0	13	20	30	35	40	45	46			
	Pressure (psig)											
	0	10.0	10.3	15.0	22.3	26.1	40.0	53.7	57.8			
R3-A	0	-12	60	84	132	156	140	100	92			
R3-B	0	0	-16	-22	-28	-30	-36	-56	-60			
R3-C	0	2	-40	-56	-84	-100	-92	-72	-66			
R4-A	0	0	136	200	291	359	319	239	227			
R4-B	0	0	0	2	20	34	36	36	30			
R4-C	0	4	-84	-122	-178	-218	-198	-144	-134			
R5-A	0	-8	52	84	124	156	132	92	84			
R5-B	0	-8	12	26	62	82	70	60	54			
R5-C	0	-6	-26	-32	-30	-32	-32	-32	-32			
Minus sign indicates compression												

TABLE V

DEFLECTION DATA

Gage Number	Time (sec)											
	-34	0	13	20	30	35	40	45	46			
	Pressure (psig)											
	0	10.0	10.3	15.0	22.3	26.1	40.0	53.7	57.8			
EDI-1	0	0.0002	0	0.0004	0.0014	0.0014	0.0020	0.0040	0.0044			
EDI-2	0	0.0020	0.0066	0.0114	0.0180	0.0220	0.0276	0.0340	0.0360			
EDI-3	0	-0.0010	-0.0030	-0.0066	-0.0104	-0.0120	-0.0150	-0.0180	-0.0184			
EDI-4	0	-0.0002	0.0024	0.0038	0.0058	0.0064	0.0056	0.0044	0.0040			
EDI-5	0	-0.0002	0.0030	0.0040	0.0060	0.0074	0.0060	0.0036	0.0032			
EDI-7	0	0	0.0032	0.0038	0.0054	0.0060	0.0046	0.0024	0.0020			
EDI-8	0	-0.0016	-0.0040	-0.0060	-0.0094	-0.0106	-0.0120	-0.0136	-0.0140			
EDI-9	0	-0.0018	-0.0076	-0.0124	-0.0220	-0.0270	-0.0336	-0.0398	-0.0400			
EDI-10	0	-0.0136	0.0068	-0.0012	-0.0172	-0.0268	-0.0692	-0.1080	-0.1172			
EDI-11	0	0.0012	-0.0108	-0.0200	-0.0356	-0.0568	-0.0488	-0.0348	-0.0328			
Minus sign indicates compression												

DISTRIBUTION LIST

FINAL REPORT W2SD-20 STRUCTURAL DEVELOPMENT TEST (U)

MTI-480

Copy No.	Recipient	Mail Stop
1	Hq. BSD (AFSC), Norton AFB; Attn: BSRPQ-1	
2	Hq. BSD (AFSC), Norton AFB; Attn: BSRPQ-2	
3	STL, Norton AFB; Attn: Mr. R. L. Greengard	
4 thru 8	STL, Redondo Beach; Attn: Mr. R. J. Brown	
9 thru 18	Armed Services Technical Information Agency, Arlington 12, Virginia	
19 thru 22	Central Intelligence Agency, Washington 25, D. C.	
23	HQ OOAMA (OOYI), Hill AFB, Utah	
24	ABL; Attn: Mr. J. C. Foster	
25	HPC, Rocky Hill; Attn: Mr. L. B. Johnston	
26	D. W. Austin	100-K-2-8
27	T. W. Barnes	100-K-2-6
28	G. M. Crook	11-K-2-8
29	R. E. Folsom	111
30	R. G. Foust	100-K-1-6
31	W. L. Gunter	100-K2-0
32	M. F. Jensen	11-K-2-8
33	J. L. Knearem	100-K-2-0
34	T. I. Lester	11-K-2-8
35	J. H. Main	505
36	R. R. Russell	100-K2-6
37	J. N. Sherman/R. L. Schaefer/J. N. Bohn	100-K-1-0
38	E. F. Shultz	100-K-2-0
39	D. E. Wachs	703
40	E. P. Whaley	100-B
41, 42	Publications Library	702
43, 44	Library/Central File	509-C
--	J. L. Morse (letter only)	502
--	A. H. Nielson (letter only)	81-16-1
--	S. E. Patti (letter only)	--

cc 718